NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

March 27, 2018

Video Study

NTSB Case Number:
HWY17MH009

A. ACCIDENT

Location:	Chattanooga, Tennessee
Date:	November 21, 2016
Time:	3:20 p.m.
Vehicle:	Thomas school bus operated by Durham School Services

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

For a summary of the accident, refer to the *Crash Summary* report in the docket for this investigation.

D. DETAILS OF INVESTIGATION

The main purpose of this study was to estimate the speed of the school bus at the time of the accident based on videos recorded by cameras installed in the bus.

School Bus Cameras

The school bus was equipped with a three-camera video recording system manufactured by Seon. The digital video recorder (DVR) was a Seon four-channel Trooper Plus model. All the cameras were installed internally and had 720x480 resolution. Camera No. 1 was near the front of the bus and was aimed toward the rear of the bus, recording passengers. Camera No. 2 was near the front of the bus and was aimed at the loading door. Camera No. 3 was near the rear of the bus and was aimed

toward the front of the bus. Cameras No. 1 and No. 2 had frame rates of 3.75 fps. Camera No. 3 had a frame rate of 7.5 fps.

Speed was estimated based on reference points that were visible through the loading door windows and the side windows of the bus. The reference points were visible in the videos and also could be identified in Google Earth images. Videos from the three cameras were used for derivation of independent speed estimates that were in close agreement with each other. Additionally, Camera No. 3 captured the image of a vehicle that was moving in the opposite direction on the accident road at the time of the accident.

Figure 1 shows an overhead Google Earth image of the accident area. The school bus was moving south on Talley Road, rolled over, and impacted a tree south of Sunset Avenue. The location of the impacted tree is marked in the figure. The red line in the figure marks the segment of Talley Road along which speed was estimated. Five reference locations are marked along the road segment. Distances between these reference locations were used for estimating the speed of the bus based on travel times between these locations. The travel times were estimated based on video frame timing.

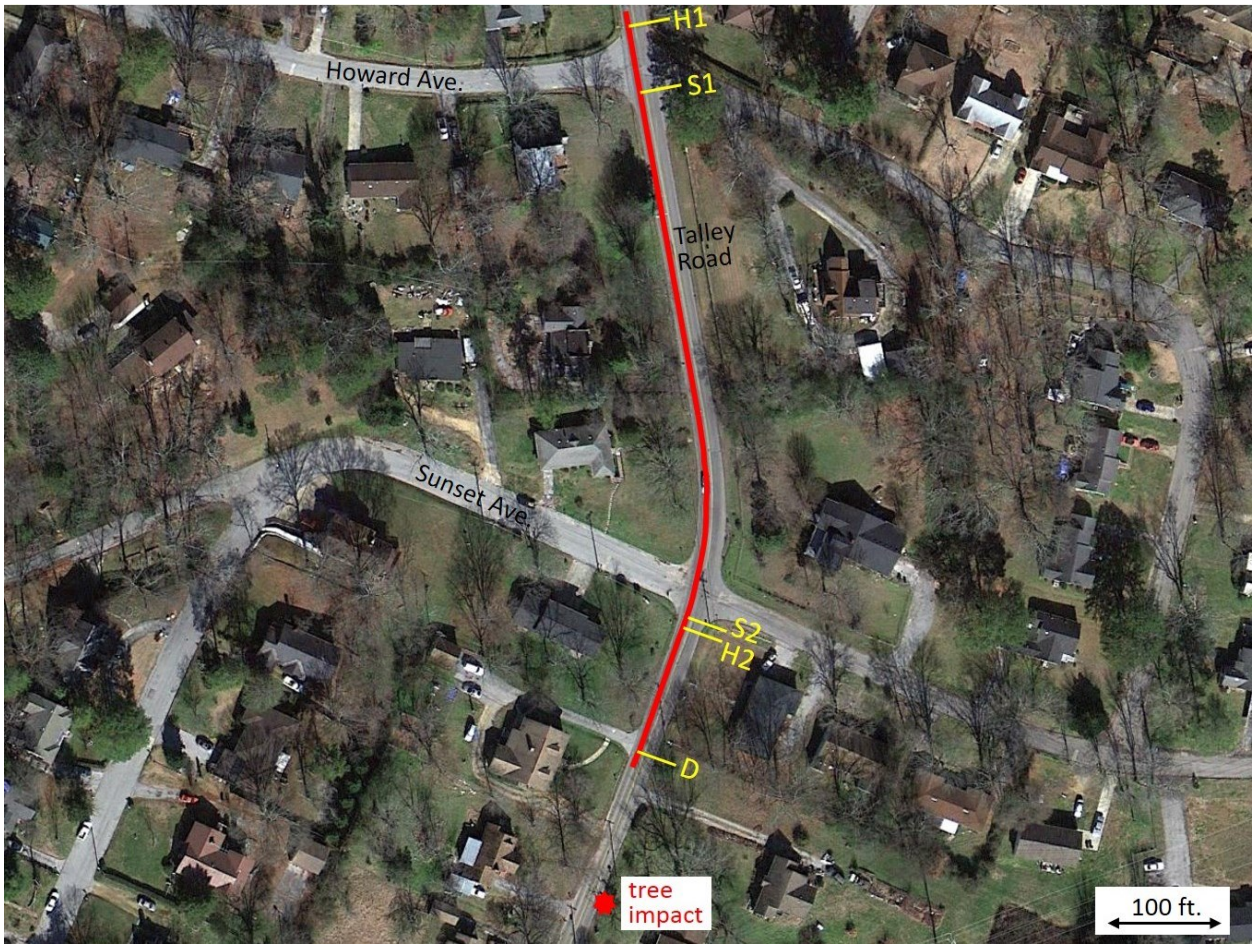

Figure 1. Google Earth Image of the Accident Area

The reference locations along Tally Road that are marked in Figure 1 are:

H1 fire hydrant No. 1
S1 brick sign 'Hemphill Neighborhood' No. 1
S2 brick sign 'Hemphill Neighborhood' No. 2
H2 fire hydrant No. 2
D south edge of a paved driveway

Figure 2 shows a subset of a frame from Camera No. 2 video. Brick sign S2 and fire hydrant H2 are visible and marked in the frame.

Figure 2. Frame from Camera No. 2 Video

Estimated Speed in Segment H1-H2

The hydrants were seen in Camera No. 1 video. The H1-H2 travel distance is approximately 508 feet and the time to travel this distance is 6.67 seconds. The estimated speed is 76.2 ft/s or 52.0 mph.

Estimated Speed in Segment S1-S2 (based on Camera No. 2)

The brick signs were seen in Camera No. 2 video. The S1-S2 travel distance is approximately 444 feet and the time to travel this distance is 5.73 seconds. The estimated speed is 77.5 ft/s or 52.8 mph.

Estimated Speed in Segment S1-S2 (based on Camera No. 3)

The brick signs are seen in both Camera No. 2 and in Camera No. 3 videos. Estimating the speed based on Camera No. 2 video is simple because the camera is oriented to the right side of the bus and the signs are seen through the loading door windows. Therefore, determining when the bus was at the sign locations is straightforward.

Estimating the speed based on Camera No. 3 video is more complicated. The camera, mounted at the rear of the bus, sees the signs through a right side window near the rear of the bus. When the camera sees sign S1, the bus is on a straight road. When the camera sees sign S2, the bus is on a curved segment of Talley Road, north of Sunset Avenue. Additionally, sign S1 is closer to the road than sign S2. Because of these two factors, the bus travels about 36 feet less than the 444 foot road distance from S1 to S2 when the signs are seen in the same right side window of the bus.

The traveled distance is approximately 444-36=408 feet and the time to travel this distance is 5.33 seconds. The estimated speed is 76.5 ft/s or 52.2 mph.

Estimated Speed in Segment S2-D

The brick sign and the driveway were seen in Camera No. 2 video. The S2-D travel distance is approximately 123 feet and the time to travel this distance is 1.64 seconds. The estimated speed is 75.0 ft/s or 51.1 mph.

Combined Speed Estimate

The above four speed estimates can be combined into one estimate that covers the approximately 623 feet of analyzed road segment, from H1 to D. The school bus traveled this segment in approximately 8.2 seconds. The estimated speed is 52±1 mph.

Second Vehicle at the Accident Location

Camera No. 3 captured the image of a second vehicle, a white car, pickup truck or van, that was traveling north on Talley Road at the time of the accident. The white vehicle is seen in the video frame in Figure 3. The school bus and the white vehicle were at the same location along Talley Road less than two seconds after the bus steered to the right to follow the curve on Talley Road at Sunset Avenue.

Once the bus was past the second vehicle, it yawed abruptly to the left, subsequently rolling over to the right. Less than one second after the two vehicles were at the same location along the road, the video ended.

Figure 3. Video Frame Showing a Second Vehicle

The abrupt yaw to the left could not be appreciated based on references outside of the bus because of poor visibility. However, motion of passengers and of an object on the dashboard, visible in the videos, clearly indicated that such yawing took place.

Figure 4 shows the approximate locations of the school bus and of the second vehicle on Talley Road. B2 and V2 show the bus and the vehicle at the time the frame in Figure 3 was acquired. B1 and V1 show the bus and the vehicle 2.5 seconds before the frame in Figure 3 was acquired. The location of V1 is based on assumed speed of 25 mph of the second vehicle. Its speed cannot be estimated based on the videos.

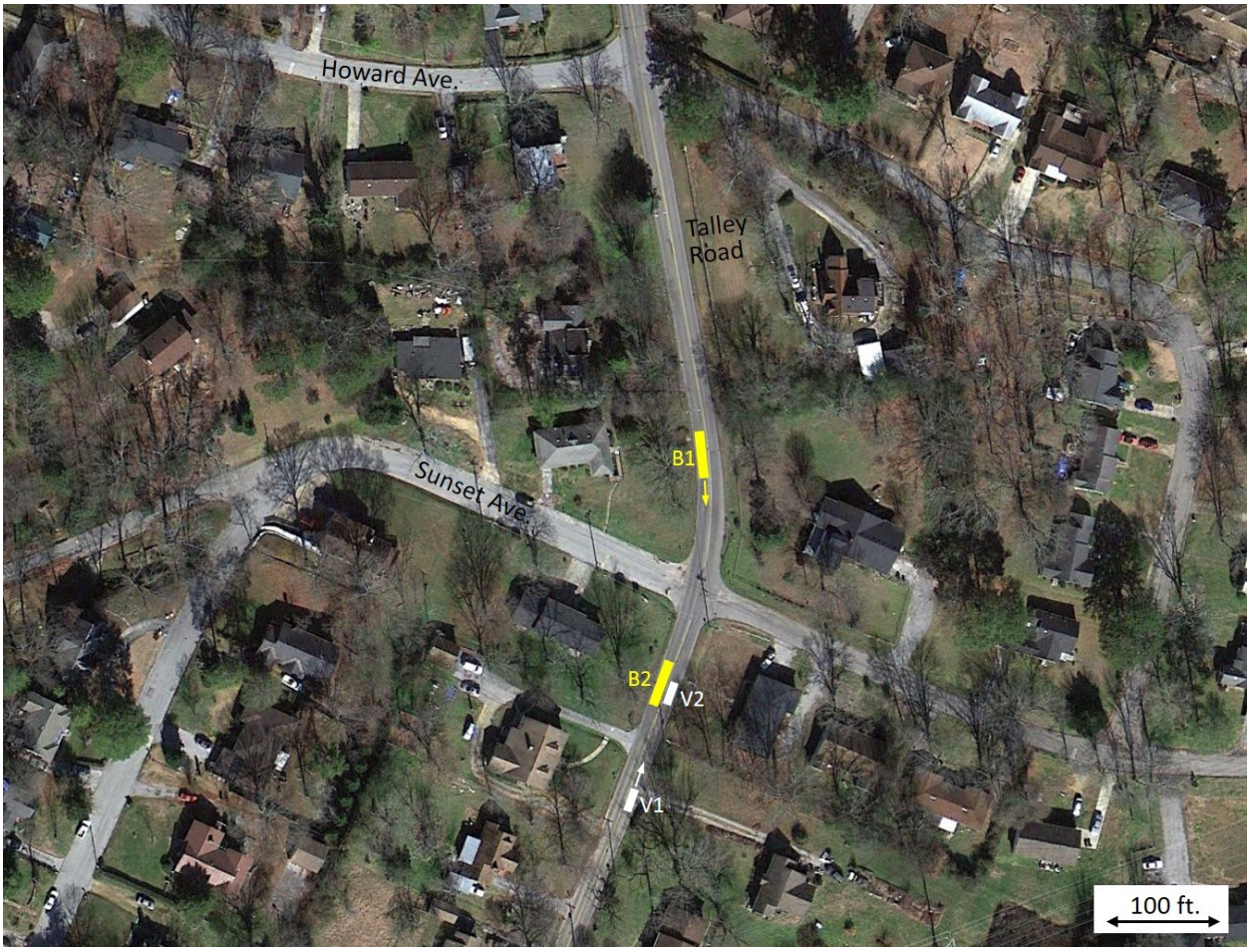

Figure 4. Google Earth Image of the Accident Area Showing Vehicle Locations

Lateral Acceleration on Tally Road Curve

As can be seen in Figure 4, Talley Road changes its direction by 31º to the west from the segment north of Sunset Avenue to the segment south of Sunset Avenue. The radius of the curve connecting the two segments is approximately 300 feet. The lateral acceleration of a vehicle negotiating a circle with 300-foot radius at the speed of 52 mph is 0.60 g. Since the school bus traveling at 52 mph was only about two seconds on the short curved segment of Talley Road, simulations were performed to estimate the maximum acceleration the accident bus would have developed.

The road and the school bus were modeled with TruckSim vehicle dynamics simulation software. A simulated driver was steering the bus along the curved road. Simulations performed with various parameters of the simulated driver showed periods of elevated lateral acceleration in the range of 1.8 seconds to 2.0 seconds and maximum accelerations in the range of 0.55 g and 0.59 g. Simulated tire slip angles on the curve reached 6º. Both the lateral accelerations and the slip angles were well above what is experienced during normal driving. If the school bus was traveling on a circle with 300-

foot radius at the posted speed limit of 30 mph, the acceleration would have been only 0.2 g.

E. CONCLUSIONS

The speed of a school bus that rolled over and impacted a tree was estimated along a 623 feet long road segment that ended approximately 132 feet before the impacted tree. The bus traveled this segment in approximately 8.2 seconds. Four speed estimates were derived based on videos from three cameras that were installed in the bus. The estimated speed along the analyzed road segment is a constant 52±1 mph.

The video from one of the cameras captured the image of a white vehicle that was traveling north on the accident road at the time of the accident. Less than one second after both vehicles were at the same location along the road, the video ended due to the accident event.